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On the Physiography of an Area
in the
North-Eastern Tranvaal (A)
and an Area in
Northern South-West Africa (B)

BY
M. S. TALJAARD

(*Merensky Publication*)
No. 1

NASIONALE PERS, BEPERK, Capetown.
1938.

On the Physiography of an Area
in the
North-Eastern Transvaal (A)
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Northern South-West Africa (B)

PREVIOUS INVESTIGATIONS.

The areas which are described in the following pages have come under observation before now. Mellor and Trevor[1]) mentioned the fact that strike faults probably existed along the longitudinal valleys in the Zoutpansberg Mountainland.

Dr. A. L. du Toit in conversation mentioned his observation that the Zoutpansberg mass was bounded on the north side by a fault (especially in the region of the Salt Pan).

Dr. du Toit[2]) has also remarked on the presence of pebbles which cap the Lebombo Rhyolites in the vicinity of the Lookwe beacon and on the beacon hills Shakashaiengwe and Shamariri between the Letaba and Olifants Rivers, and he states that this points to the existence of a lengthy period of active planation following the development of the Lebombo Monocline. "The wonderfully even crestline of the Range, and the way in which the tilted rhyolites are transected, indicate a lengthy period of active planation, etc. The trough of the Lowveld could not then have been in existence, and the Lebombo peneplain must have extended westwards to meet the higher ground in that direction." Kanthack[3]) has admirably described the hydrography and physical features of the country along the south side of the Cunene, from Erickson's Drift to the Rua Cana (Kambele) Falls and I differ from him only in the description of the various rock horizons traversed by the stream.

Beetz[4]) has described rocks similar to mine belonging to the Chella Formation (Angola) but from an area further to the west. An accurate survey will establish the true succession of the various horizons, and seeing that my views are based on a reconnaisance only, they are of course open to correction. At the Rua Cana Falls locality the exposures below the tillite are completely obscured by a mantle of surface limestone.

(A) The Pietersburg Plateau Region (1).
The Zoutpans Mountainland (2).
The Lowveld and adjoining Portuguese Territory (3).

(B) The Cunene valley from Fort Rossadas (Angola) to Swartboois-drif (S.W.Afr. Territory).

The kindness of Dr. Hans Merensky has enabled me to examine the areas to be described, and I wish to thank him and the Council of the University of Stellenbosch for granting this opportunity for physiographic study.

(A) Three separate areas have been mentioned in this sub-title and with a definite view. Territorially these areas adjoin. Physiographically they differ widely as regards form and climate. Structurally in the geologic sense, they are sometimes definitely connected, and then again show differences due to tremendous time gaps.

A glance at the rainfall map will show that the present day climatic conditions vary sharply from one region to another.

(1) The Pietersburg Plateau is a high lying plain (3,000—4,000 ft. above sea level) with rather curious boundaries. It is hemmed in on the north-, west-, and south sides by ranges, built mainly of sedimentary rocks which dip outwards: The Zoutpansberg on the northern boundary, the Waterberg in the west, and the Chuniesberg in the south.

The trend of these boundaries conforms closely to the strike of the beds which build the various ranges. On the eastern side the plateau is terminated almost completely by a step leading down to the so-called Lowveld. The step is plainly a scarp whose edge seen in plan, is serrated, due to dendritic attack by east-flowing streams.

The plateau surface is gently undulating, covered for the greater extent by grass, stunted bush appearing on isolated koppie slopes and along streambeds.

The average annual rainfall of the central plateau region is in the neighbourhood of 15 inches per annum. It is seasonal, a long dry season prevailing from April to November as a rule.

The largest stream, the Zand River, has reached a stage where it is unable to transport its load, which seems to be far in excess of its carrying powers.

In the west and central regions the outflow is towards the north by means of old-mature channels. The plateau is also drained southwards through channels such as those of the Zebedelas, Chunies and Malips rivers. These flow through "poorts" in the Chunies-Strydpoort range, and if these "poorts" are considered to belong to the class cut by superimposed or antecedent streams, I wish to mention that immediately east of Chuniespoort on the south side of the range, a "poort" has almost been cut to completion by a tributary of the Chunies river. This stream is cutting a channel by head-erosion into a dip-slope of Black Reef Quartzite and is therefor neither of antecedent nor of superimposed nature. The southern drainage seems not to have played an important role in the planation of the plateau surface and appears younger than the period of planation.

The only east-flowing system which has helped in the planation of the present-day plateau surface is the Pafuri, evidently in a mature stage of development.

At present, the plateau is being actively dissected from the east and in smaller measure from the south; westwards and northwards it shows features which began their development quite probably at the close of the deposition of the Karroo Beds. Locally there is no direct evidence to this effect, but the development of the Lowveld area points to such a conclusion. We have to deal here with a plain, quite obviously a stripped landsurface, on whose wide expanse one finds the remains of an even older landsurface—in the form of island mountains. They are being quietly removed by weathering processes, erosion not being an active process except on the eastern limits.

The low relief of the plateau I would ascribe to (a) The virtual absence of active erosion processes, (b) The uniform nature of the material underlying the plateau surface.

The material produced by rock disintegration and decay is not readily tıansported, and soft contours result. The effect is fairly general because the material subjected to the processes of disintegration and decay varies little from place to place. Except for the presence of a large S.W.-trending body of metamorphosed sediments of Swaziland System age (S. & S.W. of Pietersburg) the rest of the plateau is built of Archean granite-gneiss. The hard, resistant quartz schists and ironstones of Mt. Maré and Ysterberg form prominent elevations, and locally, quartz veins can be followed on the surface because of their greater resistance to weathering. Nowhere on this plain surface did I see any deposits laid down by streams, either those draining the area at the present day or others which belonged to an older erosion period. For the greater part then the plateau surface presents features which indicate "old age"; this is seemingly contradicted by the presence of two erosion terraces along the Pafuri beyond Spelonken. One also receives the impression that their development progresses upstream. It is in this region that I see the extension to the north, of that sharply defined step just a few miles to the south. The "step", nowhere so clearly displayed as at Mabola Kop, is the more advanced equivalent of the Pafuri terraces. For a considerable distance the Pafuri valley stretches diagonal to the "step", the Lowveld at the "step" foot gradually merging with the "old" division of the Pafuri system further to the east.

(2) The Northern barrier of the Pietersburg plateau deserves particular description:

This rugged mountainland has been carved out of an accumulation of quartzitic sediments clays and lavas, covered partly and unconformably by a younger group of sediments and volcanic products of Karroo age. How far the lower group of sediments extended southwards over the granite-gneiss surface of the plateau I do not venture to guess. A small outlier of Waterberg sandstone still exists near the south entrance of the Zand river. Its distance from the main mass is small. The fact that so few streams flank the berg on the southside, and that the majority cross it in a direction nearly at right angles to the strike of the rocks and the trend of the flank, makes me think that its former southward extension was small. Lateral

stripping of surface rocks is mainly accomplished by tributaries, and in this case any outliers would not have been removed if they had ever existed at all.

That the Zoutpansberg mass north of Louis Trichardt was once continuous with the Blaauwberg mass in the west can hardly be doubted, and in that case the disposition of the beds today gives a clue to the type of floor on which these sediments were deposited; namely a dome-shaped floor of low curvature.

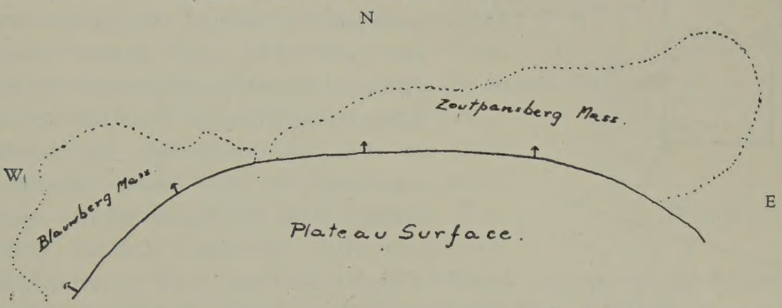


Fig. I.

The variation in the Waterberg sediments is of such a nature that it favours the suggested mode of deposition. Before I attempt a physiographic description I would like to mention the various lithologic horizons met on field traverses. One traverse was made in the Zand River valley, quite a number north of Louis Trichardt, various excursions at and in the neighbourhood of the Entabeni Forest Reserve east of Louis Trichardt, and one at the south entrance of the Pafuri further north-east. In the central area around Louis Trichardt, and to the east, the basal bed in the series, resting on granite-gneiss, seems always to be a lava. This rock and its associates have been described by Dr. A. W. Rogers. At Entabeni they are interbedded, higher in the series with sandstone, shale and quartzite beds. I think the formation here attains its greatest thickness in the Zoutpansberg, with Vera Point situated on the Upper Main Quartzite horizon. The volcanic rocks vary in vertical distribution, in thickness of the horizons, and in texture, from Louis Trichardt eastwards. They seem to weather easily in the regions of high rainfall, and form deep reddish soils (Klein Australia) evidently highly suited to afforestation.

The following is a rough table of the succession of the various horizons at Entabeni.

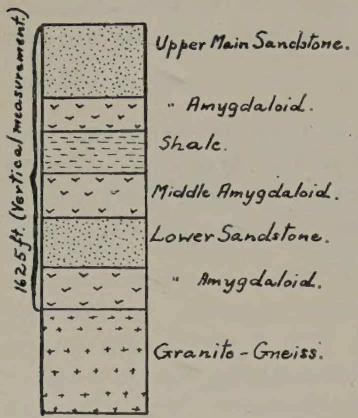


Fig. II.

At Louis Trichardt, westwards for a few miles and at the Pafuri Gorge in the north-east, these volcanic beds form fairly distinct outcrops, though they never build prominent features in the landscape. The shales, sandstones and quartzitic sandstones as well as the conglomeratic beds (Pafuri gorge) have a typical purplish-red colour. The sandstones and quartzites are mostly coarse grained, though cross lamination and sporadic lenticles of finer texture are of common occurence; the former especially in the lower sandstone horizon and the latter in the upper quartzitic horizons. Quartz grains loosened by weathering from the lower horizons show a remarkable degree of rounding, with frosted surfaces, and this feature coupled with the fact that cross lamination also occurs in these beds, seems to indicate that atmospheric transportation may have played a part in their history. Little remains to be said about the shale and conglomerate horizons. The former has a soapy feel, it is extremely soft and friable and forms a clayey mud soil of purplish colour. A conglomeratic facies occurs in the upper main quartzitic horizon but its greatest development was found in the Pafuri Gorge where it is situated much lower in the series. Of great interest here is the remarkable spherical shape of the conglomerate pebbles — mostly milky white quartz and jasper.

The cement is purplish-red and mainly granular quartz. The conglomerate is interbedded with amygdaloid. These sediments whether of terrigenous or volcanic origin are all conformable as to dip and strike, locally, though these vary from place to place. Along the south flank of the range the dip varies from 30°N 5°W near Louis Trichardt and Entabeni to 10°N 5°W in the Pafuri section.

On the Louis Trichardt-Messina road the highest dips were measured on the southern flank of the mountainland. The angle decreases tot 22 degrees and even 20 degrees further northwards, though the strike remained unchanged.

Former investigators (Mellor and Trevor) have noticed and remarked upon the presence of successive longitudinal valleys traversing the mountainmass more or less parallel to the strike of the beds. This feature can be studied to the best advantage on the road from Louis Trichardt to Messina. One passes through at least four main ranges of Waterberg sediments, separated by valleys of varying width and length. These valleys are sometimes connected by poorts or narrow defilies e.g. Wylliespoort. The shape of these valleys is peculiar. They widen and narrow suddenly, their floors slope to one side—the north—and the valley side on that flank is usually steep, and built of quartzitic sandstone seen in strike section. The south flank is a dipslope, built mainly of quartzite, partly of amygdaloid (in handspecimen the same material that floors the formation on the extreme south flank). The accompanying sketch is a diagramatic section of the part now being described.

I cannot think how such a duplication of beds in the dip direction can occur except in consequence of strike-faulting; and this explanation has been adopted in the construction of the section. The longitudinal valleys are sometimes linked by very narrow poorts of peculiar shape. Wylliespoort is a typical example. The walls of the poort are remarkably steep, approaching the vertical; large smooth rock surfaces are exposed, and the trend of the poort conforms to the strike of joint planes. I believe that the stream now flowing through the poort merely widened two sets of vertical joint planes and, helped by block weathering, joined the two longitudinal valleys. The Zand River poort in part presents features which suggest a similar mode or origin. The valley makes a succession of bends which are nearly right angles, some parts being directly parallel to joint plane directions.

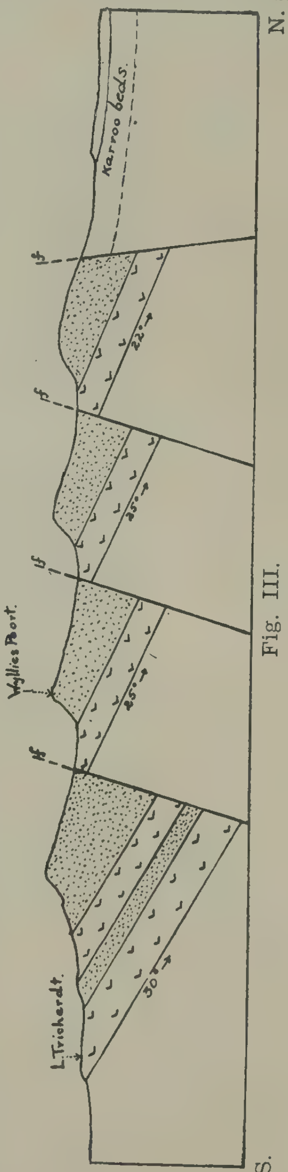
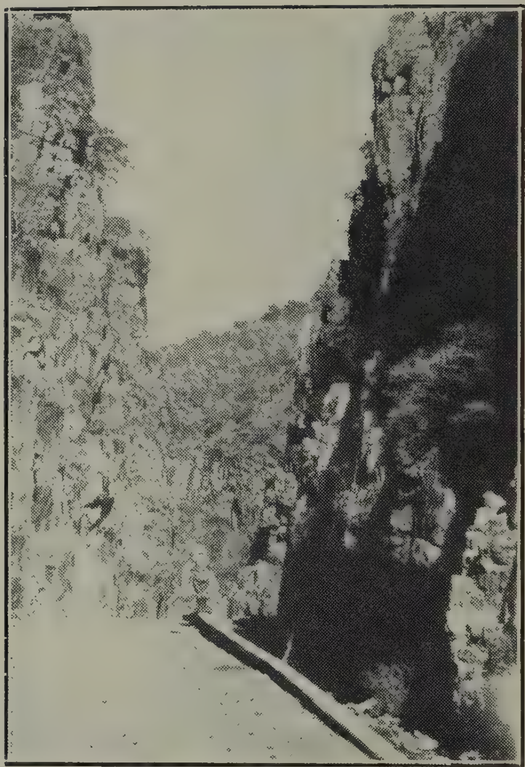


Fig. III.



Wyllies Poort, Zoutpansberg.

The fundamental features of this mountainland have been determined firstly by its geological structure, and secondly in no small degree by the variation in the nature of the various rock components. To what extent the Karroo rocks covered the Waterberg sediments, and of what age the suggested strike faults are, I am unable to say, but the fact remains that weathering processes, in past ages as well as under present day conditions, are etching out the various horizons exposed to atmospheric agencies. The change in climatic conditions from the north to the south, in the region east of Louis Trichardt is sudden. Soil production is high on the south flank in this region, but after the first range has been crossed block weathering under semi arid conditions takes its place. North-east of Chibase the change is not so sharp, the south flank is lower, and this inlet of high rainfall has brought the Motale river in the interior of the berg to a mature stage, its flood plains being under active cultivation by natives. This valley presents features produced only under stable conditions.

West of Louis Trichardt, low rainfall conditions produce features similar to those on the north flank of the mountainland, and the easily weathered amygdaloid is seemingly absent in the part west of the Zand River entrance. Detailed mapping will be needed to clear up this point.

Just north of Louis Trichardt the various horizons most clearly display their varied powers of resistance to weathering under semi-humid conditions. The berg rises in steps, the short steep fronts of which are built of the quartzitic beds, the tops of amygdaloid (see section).

This mountainland, as far as its physical features are concerned is undergoing a slow but progressive change, because the high rainfall area seems to be confined to the same direction as the encroaching escarpment edge south of Elim.

(3) *The Lowveld Region.*—To define the limits of this region is difficult, because so many ideas prevail as to the meaning of the word „Lowveld." To the botanist it means one thing, to the geologist another, perhaps the student of wild animals has another meaning and the farming community has vague and varying conceptions of this expression.

Climatologically it should possess a western limit—that great climatic barrier the Great Escarpment. Geologically it is not to

be so confined because a great variety of rock types and rock structures are to be found within this region. I think it can be restricted to physiographic limits, as far as the shape of the land surface is concerned.

The Great Escarpment varies tremendously in surface shape along its trend. Where the step is cut only in one rock type e.g. granite-gneiss, it is usually steep. As soon as a protecting cover of resistant sediments is encountered e.g. Black Reef Series the decline is by means of steps. The highest step with a sharp steep front, is usually cut in the lower quartzitic horizon of the Black Reef Series, the lower steps in gneiss or metamorphosed sediments and intrusives of the Swaziland System.

This step-like or sharp decline leads down to a lowlying region stretching eastwards to the Portuguese East African Territory. In the north-eastern sector this plainlike region has a low average rainfall; southwards conditions become more humid, though the region as a whole enjoys only seasonal rainfall.

Geologically this lowlying area would reach to what is known as the Lebombo Range, a low scarp built of Karroo volcanics, which trends more or less due north-south, in the vicinity of the west boundary of Mozambique (P.E. Afr.); but this socalled mountain range, though attaining considerable altitude on the eastern border of Swaziland, drops down to a low scarp ridge further north, and in the north-eastern part of this area, this ridge disappears under a cover of old Limpopo gravels.

Wherever the Lebombo is worthy of being termed a range it is multiple, with dipslopes disappearing gradually eastwards beneath a cover of beds of Cretaceous age in the Mozambique region. In a broad sence the latter territory is also a plain, which slopes gently to sea level.

Measurements showed that certain points on the Lowveld plain, in the vicinity of Satara (Kruger National Park) were higher than the top of the neighbouring Lebombo scarp near Isweni. As a matter of fact if a section were drawn from the Great Escarpment to the coast in this north-eastern sector, and the vertical scale were not enlarged, then the Lebombo scarp would not appear as an elevation at all, and one would receive the impression of a gently curving plain surface, extending from the base of the Escarpment to sea level.

On this Lowveld plain isolated koppies, and ranges of low hills appear. They are invariably built of rock types of a composition differing from that of the granite-gneiss. Selective processes have evidently been at work in producing these features. The Sutherland Range (a group of hills), the Murchison Range, the Mashishimala Hills and the Palabora Hills, are the best known geologically. I did not mention the Barberton Mountainland, because it is still intimately linked up, physiographically with the Great Escarpment itself. The Sutherland and Murchison ranges are built of crystalline schists, metamorphosed quartzites etc., and judging from the results of the present day, these rocks are more resistant in withstanding the attacks of subaerial erosion and weathering than the granite-gneiss.

The Mashishimala and Palabora hills are built of non-gneissic granite which is always more resistant than the gneiss. At present these elevations on the plain are eroded only seasonally, by small tributaries of the larger drainage channels of the Shingwedzi, Letaba, Olifants and Selati rivers. These tributaries only contain flowing water during the rainy season and as a rule the load is far in excess of the competency. During the dry season, coarse sand and boulders are seen to clog the channels, right up to the sources, and hardly any transportation takes place even in the major drainage channels during the dry season.

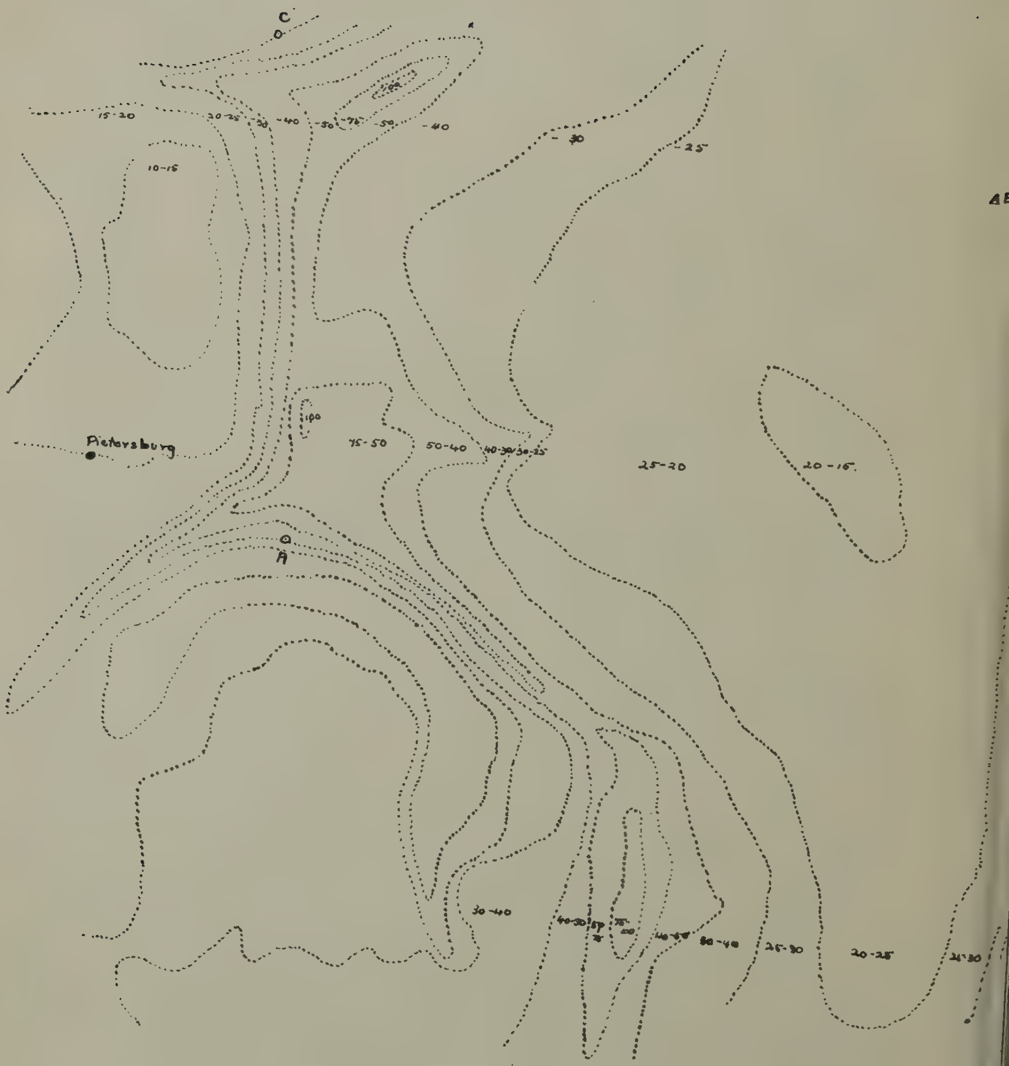
In great measure, the local direction of flow of the streams draining this area is determined by the foliation direction of the granite-gneiss. The young divisions of the Klein, Middle and Great Letaba, and the young-mature reaches of the Selati, display this control most clearly. Quite normal granitic types are met with in this area, the banding and foliation being best developed in the vicinity of the large inclusions of altered rocks of the Swaziland System.

Generally, transportation of load is an interrupted process along the courses of all these rivers, due to low competency, with the result that this process is only active all year round in the extremely young divisions of the channels.

The Olifants and Blyde rivers have their sources beyond (i.e. west of) the Great Escarpment, which they cross in gorges of antecedent origin. With the exception of the Pafuri, all the other streams draining this plain, have their sources in the Escarpment, the Great Letaba having advanced so far as to capture the supply of the

MEAN ANNUAL RAINFALL.

From Map published by the Irrigation Department—1926.

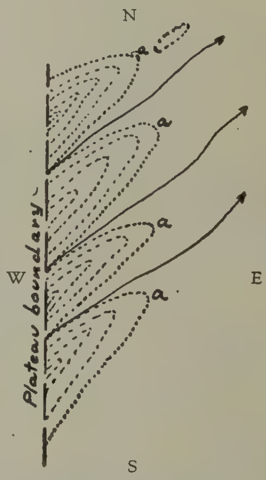



C.
Soutpansberg Range
Louis Trichardt
Pafuri R.
Shingwedzi R.
B.
Sutherland
Range
Pietersburg
Plateau.
Pietersburg
Gt. Esc. - Plateau Phase
Great Letaba R.
Lowveld Plain.
Murchison Range
Scarp - Lebombo
Selati R.
Olifants R.
Chuniespoort Range
A.
Olifants R.
Low Rhyolite
Lowveld Plain.
Great Escarpment
[Areas which are remnants of former more extensive Plain of IInd Order.]
Pafuri Terraces.
Iron Crown.
C
Soutpansberg.
Wolkberg
B.
Lebombo Scarp.
Horizontal Scale: 1/2,000,000.
Vertical " : 1/240,000.

Mathlapitsi, a south-flowing tributary of the Olifants. Weathering supplies material in such amount on the plain itself, that the valleys as well as the river channels are choked.

Planation is therefore progressing at present by weathering agencies, over the greater extent of this area. In the Escarpment region the river channels are being deepened, and lengthened to the west, resulting in a dendritic attack on the Pietersburg plateau boundary. The following effect is produced under control of the foliation direction of the granite-gneiss.

Along the south-eastern flanks, and near the upper levels of these finger ridges, waterfalls abound, and dense rainforests (where not destroyed) conserve abundant moisture, amply provided by frequent mists and a high average-annual rainfall. The Machoeba Kloof and Woodbush-De Hoek region are convincing examples. Moisture weathering has in some localities produced soils up to nearly 100 feet deep, a good storage for groundwater, with the result that numerous fresh water springs occur on the flanks of these finger ridges. Great areas of red soil occur in the neighbourhood of Duiwelskloof and Tzaneen, the colour being due to leached iron-oxide from basic dykes, which occur in great numbers and crop out frequently (varying in trend from due N. to 40 degrees E. of N.).



Dendritic attack.
a, a, a, — Finger Ridges.

FIG. IV.

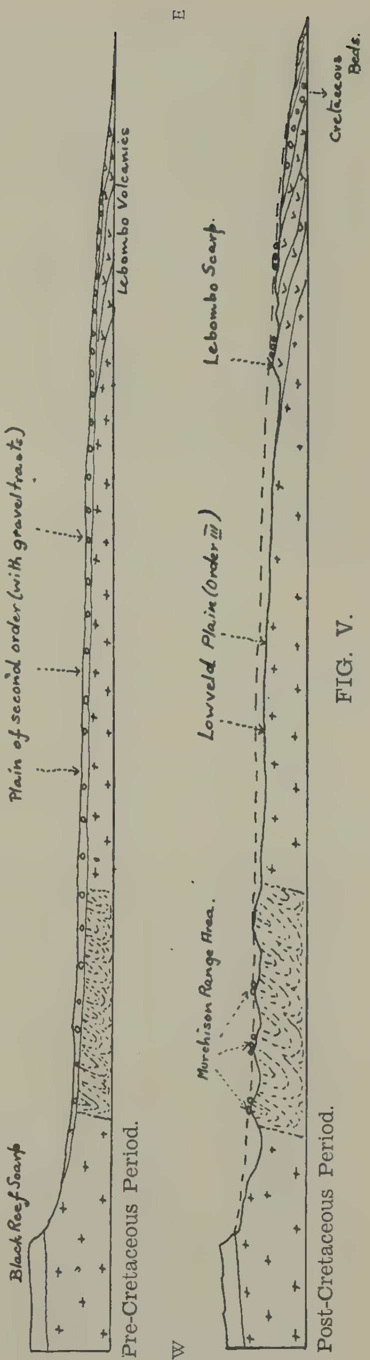
We pass next to a consideration of whether there is not a more intimate, and older connection between this Lowveld plain and the high lying Pietersburg plateau.

Firstly it must be mentioned that products of river erosion (in the form of chatter-marked pebbles) occur at various points on the top of the first or west ridge of the Lebombo. Secondly, and of equally great interest is the presence of a few scattered river pebbles on Rita Hill (Murchison Range) and on the heights near Hepsibah Mission in the Letsitele valley.

The Lebombo and Murchison Range pebbles are mainly of dark-coloured, hard, unmetamorphosed quartzite, derived quite probably

from the Black Reef Series. I did not find any rock resembling this quartzite type in any of the Swaziland System exposures which were visited. No matter from which particular horizon they were derived, these pebbles point to the existence and eastward extension of an older and higher plane of river activity than the present Lowveld surface. I look upon the tops of those hills, already mentioned, as representing what was formerly an older erosion level on which such rivers as the Shingwedzi, the Letabas, and Olifants distributed stream gravels brought from the west, at the time when the Lebombo Rhyolite scarp of the present day, did not act as an obstacle to planation of the surface.

The basal, fossiliferous, sandy conglomerates of the Mozambique Cretaceous contain many quartz, chalcedony and quartzite pebbles (Massingere), but no pebbles from the Stormberg volcanics. The cutting of the Olifants and Shingwedzi poorts through the Rhyolite ranges of to-day must then have begun at least after the deposition of the Cretaceous conglomerates, much of the detritus covering the volcanics being transported eastwards to the Cretaceous sea and there cemented in a highly calcareous, sandy matrix containing numerous remains of Brachiopods, Lamellibranchs and Echinoids.



Pre-Cretaceous Period.

Post-Cretaceous Period.

FIG. V.

The diagrams shown on the previous page would serve to illustrate the position in Pre- and Post-Cretaceous times.

The Lebombo Scarp is therefore a younger feature than the original Lowveld plain, which I would like to call a plain of the second order. I believe this surface to have been cut, mainly by river action, to a level of about the same elevation (taking into consideration the continental slope—eastwards) as the Pietersburg plateau of the present day (plain of second order).

I take it that the remains of this second order plain are embodied in the isolated ranges, and the finger ridges which are still in direct connection with the plateau.

This land sculpture appears to be progressing in a definite direction namely westwards, leaving denuded surfaces in its wake, now attacked by subaerial weathering, and in places aggraded by it. In the initial stages, the east-facing Black Reef Scarp was probably no higher above this second order Lowveld plain, than it is today above the Pietersburg plateau, along the Chuniesberg-Strydpoort Range.

The adjacent eastern plain surface was then lowered by renewed activity of the rivers. I would liken the crust motion to that of a giant ripple of low curvature. Where the activity or eroding power, which it gave birth to, met with greater resistance (due to differences in composition, texture and alignment of rocks) the progress was retarded in the horizontal though not in the vertical direction. The rim or edge of the Great Escarpment is now receding westwards to the north of the strike bend in the Black Reef Series (north of point A on the map), the homogeneity and unbedded nature of the granite-gneiss mass aiding the advance. The crest of the swell was denuded more rapidly, the sag ends being attacked later by the stream rejuvenation, which caused the cutting of poorts in the tough Lebombo rhyolites and piracy by swift head erosion in the Escarpment region (Letaba—Mathlapitsi capture). The work is being completed in the crest region of the swell, by selective weathering, which has caused the less resistant lower basalts of the Lebombo to be stripped down to and below the general level of the present day Lowveld plain

(plain of third order). This crustal disturbance has even effected the erosion of the Cretaceous beds, but not so noticeably the Recent and superficial deposits of the coastal belt (Andrade). The rivers here meet the ocean as tidal estuaries. Remains of consolidated dune sands form fringing shore reefs, approachable only at low tide, and hollows between partly consolidated dune ridges are often transformed to "vleis" or lagoons; surely a sign of present day coastal submergence even though it may be only on a small scale.

"Topography to a considerable degree determines climate; the latter in its turn leads to modifications of the former." Whether the topographic features here described, are directly or indirectly connected with the climatic stresses to which this land is subjected, lies beyond the scope of this brief description.

Before finishing this discussion I would like to summarise the sequence of events which moulded this tract of country.

(A) Erosion period, producing a land surface corresponding to or still higher than the top levels of the island mountains on the Pietersburg plateau. Pre-Karroo, and at an elevation higher than the plane of deposition of the Karroo beds in the surrounding country. Plain of the first order.

(B) Post Karroo planation to the level of the present day plateau surface. This surface reaching in a gentle curve to the coast, and passing through the higher volcanic horizons of the Lebombo axis; also resulting in a deposition of gravels over an area reaching from the base of the primary Black Reef Series scarp to the pre-Cretaceous shoreline. Plain of the second order.

(C) Uplift causing rejuvenated streams to expose the Rhyolites of the Lebombo, and deposition of basal conglomerates of the Cretaceous in the east. Birth of plain of third order.

(D) Tertiary uplift affecting the coastal region to a greater extent than the interior. Plain of fourth order. Coastal plain.

(E) A recent sag of the immediate coastline region only.

(B) — The Cunene valley from Fort Rossadas (Angola), to Swartbooisdrif (South West Africa).

The region to be described in the following paragraphs, is situated along the Cunene valley, in the vicinity of the Kavale Rapids, and between the Kambele Falls (Rua Cana) and Swartbooisdrif (Tschimako). Towards the interior of Angola, as far as Fort Rossadas, and beyond for a fair distance, the Cunene is a still flowing stream, having cut a bed in its own flood plain deposits. The south bank is steeper and higher than the north bank, with the result that flats on the north side are mostly marshy during the greater part of the rainy season.

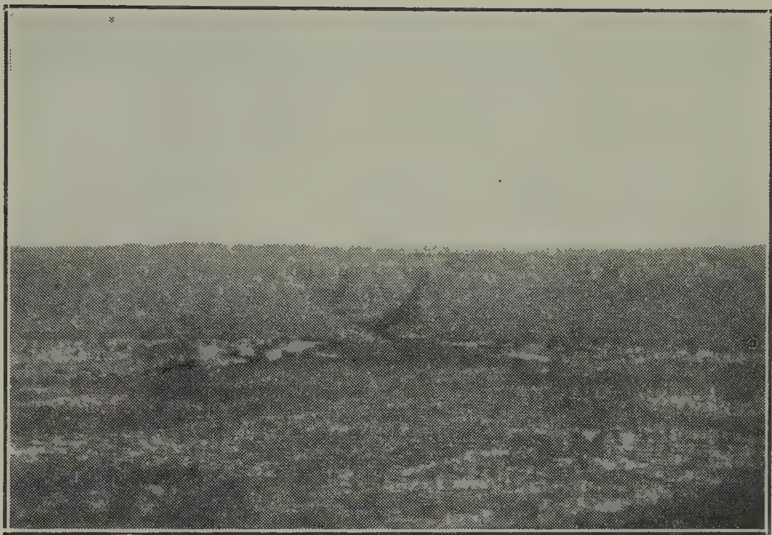
The same mature features are in evidence at Naulila further downstream. No outcrops of rock were found here, but to the south-west, at a distance of approximately 14 miles, one finds outcrops of a series of dark red sandstones with interbedded conglomerates, striking almost due E-W, and dipping N.20°. These rocks build low ridges which flank the Cunene valley, and the river bed is here stony.

About two miles further downstream the river bed is cut down to a granite-gneiss floor, and the first of the two rapids is already in gneiss. During the dry season the river flows only in the gorges which are found at the foot of each rapid, but during the flood periods I believe the upper rapid and gorge are completely hidden under the wide and swiftly flowing stream.

Dry and Wet season channels of the Cunene at Kavale Rapids. The diagram is approximately to scale.

Fig. VI.

In the vicinity of the rapids the gneiss is highly foliated and many of the foliation planes have been opened to the size of channels by bed scouring.



Looking north to gneiss plateau of Angola and southern exit of Cunene from Kambele Falls.

Looking towards first gorge at Kambele Falls, Cunene.

At the lower rapid the gneiss is brecciated and the foliation planes are wavy, and crossed by many local slip faults. Further downstream from the lower rapid the river bed becomes shallower and boulder strewn and again assumes its mature features, though flood plains are now entirely absent. On the north side of the river, for a short distance, the red sandstones continue to cap the gneiss and then disappear completely.

From here, westwards, one passes into broken country, carved in gullies and ravines whose bottoms are filled with coarse felspathic sands, gneiss detritus from weathering under semi-acrid conditions.

Broad black dykes occasionally traverse the gneiss, and form ridges which all trend more or less E-W. The highest of these would not be higher than about 50 ft. above the surface of the surrounding land. This state of affairs continues right up to the spot where the Cunene slips down into a gorge, the Kambele Falls, or Great Cataract. This gorge trends east-west and is in the neighbourhood of 300 ft. in depth, bearing a distinct resemblance (on a smaller scale) to the great Victoria Falls fissure. The plan view (Fig. VIII) may illustrate the conditions in a simpler way.

The gorge trend approximates to the strike of the foliation planes in the

Plan view of two Kavale Rapids.

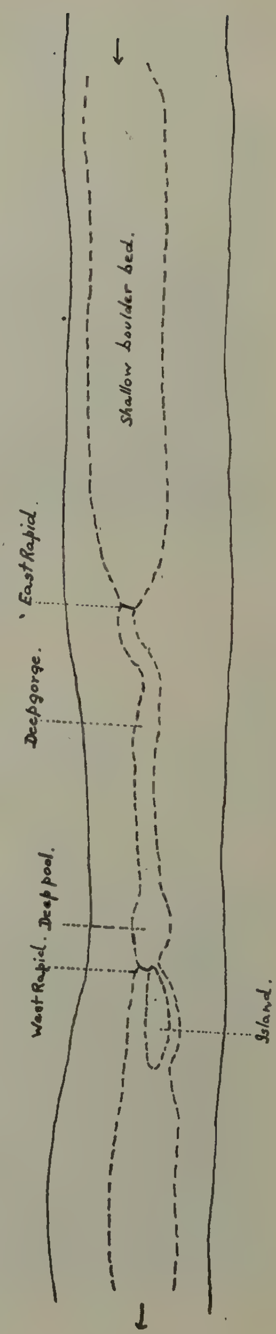
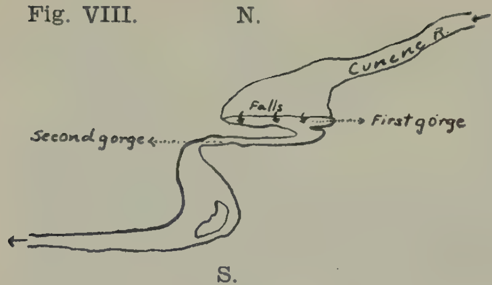


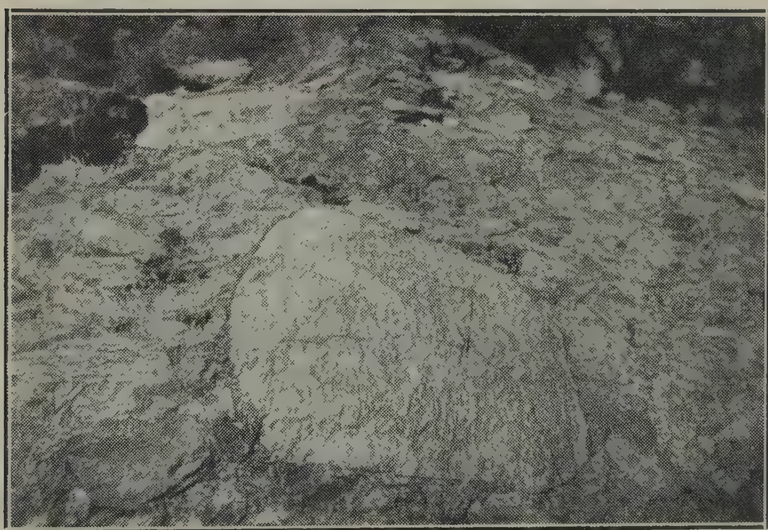
Fig. VII.

Fig. VIII.



gneiss, which here dip at about 80°N. After passing through a second and parallel gorge to the south, the river emerges beyond a steep cliff of granite-gneiss and rushes into a deep wide pool with an island near its southern extremity. The Cunene is here joined from due east by a seasonal tributary whose channel entrance is blocked by a sandbank during the dry season.

Turning at right angles and flowing about due west the Cunene hugs the northern flank of a valley of great structural interest. Due south from where the river emerges from the gorge one sees bush covered slopes rising in steps to a ridge, built of reddish felspathic sandstones. The lowest step whose front is undercut by the river south of the island, rises perpendicularly to about 50 ft.



2-foot Gneiss boulder in Tillite (?)
Groot Kakebeen Camp (S.W.A. Police) south flank, Cunene.

above the water surface. This cliff edge is covered by a surface deposit of lime. The top of the step is covered by a blackish and highly calcareous soil in which many nodular concretions of lime

Upper Kavale Rapid with gorge in gneiss, Cunene River.

Upper Kavale Rapid, Cunene River.

are present. This lower step grades up into a second step whose front is also mantled in limestone of the most fantastic form. It has the appearance of a sheet of molten wax which on reaching the edge of the step, began to drip and cool in long slender columns. They are surface stalactites. The surface is highly pitted by rain. Partly covered by this mantle of surface limestone one finds outcrops of a conglomeratic rock. The contained boulders are of gneiss only and the cement is coarse and sandy, containing all the major components of the granite-gneiss. The boulders are angular to subrounded on one or two sides, and range in size from pebbles of $\frac{1}{4}$ inch diameter to gneiss blocks 2 feet across; these features indicate a glacial origin. (See photograph on page 19.)

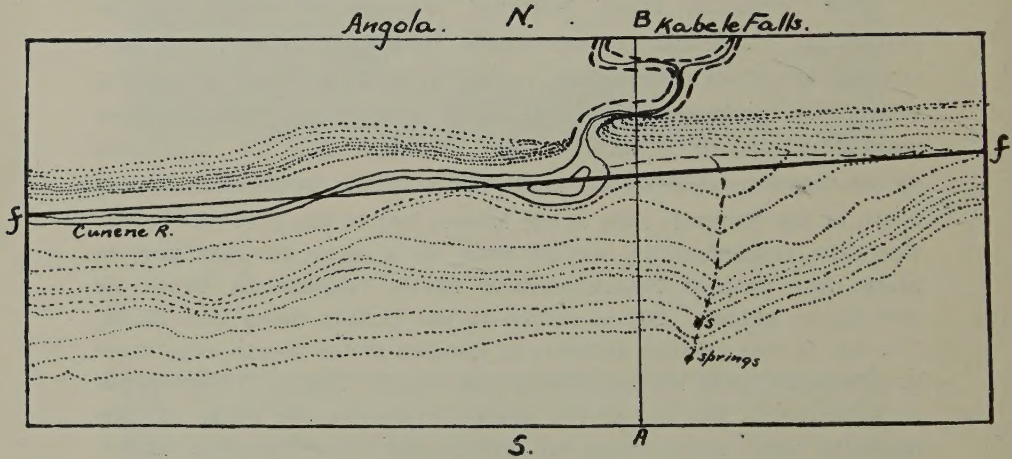
This formation shows beautiful examples of weathering by exfoliation. Its mode of occurrence (unbedded habit), and the composition of its components, suggest it to be a deposit of glacial origin. Its position between the gneiss and the red, current-ripple marked sandstones, suggests an off-shore site of deposition by floating ice. Whether it rests on the gneiss at the locality due south of the Kambele falls is not known, but to the west and south-west, the conglomeratic horizon rests on a series of dark grey to black, fine grained limestones and shales (calcareous) which lie directly on gneiss. But to return to the locality under description. The top of this granitic tillite is at the foot of the fourth step where it disappears under red sandstones and shales. This level corresponds in height with the top of the gneiss surface at the Falls. If the dolomitic series which crops out further west, is present here, underneath the tillite, then the structure suggests the presence of a strike fault, with downthrow which let the upper sediments down to a level corresponding almost to the original plane of deposition of the base of the series. The section illustrates this interpretation.

Downstream from the Kambele Falls, the Cunene flows in a valley which clearly shows all the signs of rejuvenation. A succession of terraces is superbly displayed on the south flank, and at Swartbooisdrift the lowest terrace is cut in a conglomeratic floodplain deposit on both flanks. This deposit contains waterworn boulders of all the known rock types further upstream. The distance between Kambele Falls and Swartbooisdrif is about 30 miles, and for at least three-quarter that distance the north flank is cut in gneiss, and is remarkably steep and straight.

How far this suggested fault extends westwards I cannot say, but it seems very probable that the rejuvenated stream made full use of this line of weakness, and had its direction of flow controlled by it in the later stages of downcutting.

KAMBELE FALLS.
Cunene River.

Sketch Contour Map.



S.W. Africa.

Sketch section along A-B.

Vertical scale: 1/10in. = 100ft. Horizontal: 1/10in. = 528ft.

Dip of beds = 15° S.S.W.

Summary:

(a) The great clefts at the Kambele Falls are widened planes of foliation in gneiss.

(b) The presence of earth movement of an age older than the rejuvenation of the Cunene valley, is suggested by the sudden change in level of the plane of deposition of the sedimentary series, capping the gneiss on the north and south flanks of the Cunene valley.

(c) The sediments are off-shore deposits (partly glacial in mode of deposition) in shallow water. Ripples formed by currents prove the depth range in deposition.

(d) The trend and shape of the valley of the Cunene has in this area been controlled partly by the presence of the suggested fault, partly by the difference in the structure and composition of the rock types present, and to a great extent by the rejuvenation of the stream.

(e) The prevailing climatic conditions are favourable to the deposition of surface and subsoil $CaCo_3$, by a rising and sinking groundwater level. The latter is generally high even during the dry season. Numerous flowing springs appear in the vicinity of Groot Kakebeen Camp (S.W.A. Police) during October.

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